[001] PROPORTIONAL PRESSURE-REGULATOR VALVE

[002]

[003] According to the preamble of claim 1, the instant invention relates to a proportional pressure-regulator valve. The invention further covers, according to the preamble of claim 17, a method for regulating a pressure level of a pressure medium with a proportional pressure-regulator valve.

[004]

[005] In a transmission, particularly an automatic transmission of a motor vehicle, the pressure is regulated in a hydraulic circuit according to requirements. While for the supply of lubricating oil to the parts of the transmission, the pressure level can be kept low in a hydraulic circuit, during the shifting operations the pressure has to be sharpy raised in order, for example, to be quickly able to fill shifting elements.

[006] According to the prior art, there have been used for regulating the pressure in hydraulic circuits pressure regulators which control shift valves for actuating the clutch. The shift valves are controlled within the pressure regulator by means of a proportional magnet consisting, among other elements, of a magnetic core, a magnetic coil and a magnetic armature. The proportional magnet controls here the coil current proportionally to an output variable force, that is, according to the coil current the magnetic armature and therewith the shift valve are controlled for actuating the clutch. From the resulting characteristic magnetic force-current characteristic lines of the pressure regulator are produced in an electrohydraulic control of automatic transmissions the pressure-current characteristic lines desired for clutch adaptation.

[007] In the Applicant's German Patent Application DE 100 03 896 A1, a pressure regulator is described which adjusts as needed a shift valve by means of a stationary proportional magnet, a magnetic coil, a movable magnetic armature and a specific control system thus regulating the pressure in the hydraulic circuit. The pressure-current characteristic line has a curve continuously rising from the start on, that is, as the current force increases so increases the pressure also. But in the practice, the gradient of the pressure-current characteristic line is in operation too large for the requirements so that the pressure-current characteristic line is too

steep and thereby the current sensitivity of the pressure regulation is not enough for a comfortable gear ratio. In case of a low load, that is, at low pressures, the low sensitivity makes itself noticeable specifically in a poor shifting quality.

[008]   Therefore, the invention is based on the problem of overcoming the disadvantages of the prior art and, in particular, of providing a proportional pressure-regulator valve for regulating a pressure level in a hydraulic circuit and of outlining a method by which the changes of pressure level in a hydraulic circuit are adjusted to be as comfortable as possible and showing how such a proportional pressure-regulator valve is controlled.

[009]   The problem on which the invention is based is solved by a proportional pressure-regulator valve having the features of claim 1 and a method of regulating a pressure level in a hydraulic circuit with a proportional pressure-regulating valve having the features of claim 17.

[010]

[011]   The requirement of a high pressure-current sensitivity, above all in the low-pressure range, is satisfied by a load-dependent adaptation of the pressure-current characteristic line, herebelow called a p-I characteristic line for the sake of simplicity.

[012]   The load-dependent adaptation of the p-I characteristic line of the inventive proportional pressure-regulator valve is implemented by a proportional magnet having two gaps that can be controlled independently of each other. The first gap is part of an immersion step known from the prior art which is controlled by means of induced magnetic field. Said magnetic field is produced by an electric current in the magnetic coil, it then proceeds via the magnetic armature existing in the interior of the magnetic coil, the housing and the magnetic core. An axial separation between the magnetic armature and the magnetic core by means of a non-magnetic ring results in that the magnetic field can pass over to the magnetic armature only via a radial gap. At this point, the magnetic field produces a magnetic force that acts upon the magnetic armature and moves it in axial direction depending on the magnetic force. A continuous electric control

respectively of the proportional magnet and of the magnetic coil in this manner makes possible a continuous control respectively of the magnetic armature and of a control element connected by an armature rod with the magnetic armature.

[013]   According to the invention, there is additionally obtained respectively via a second gap and a second immersion step, a targeted weakening of the magnetic field.   The second gap is implemented by using an inventive magnetic core consisting of at least two parts, specifically a first and a second part.

[014]   The first part of the magnetic core is firmly connected with the housing, located concentrically and axially movable around the armature rod fixedly connected with the magnetic armature. The first part of the magnetic core projects partly into the interior of the magnetic coil.

[015]   The second part of the magnetic core is, likewise coaxially, concentrically and axially movably disposed around the armature rod. But the second part, contrary to the first part firmly connected with the housing, is axially freely movable. The second part of the magnetic core is, therefore, implemented in the manner of a sliding part which is situated adapted to be laid on the first part and preferably provided axially between the first part of the magnetic core and the housing.

[016]   This division of the magnetic core in a first part firmly connected with the housing and a second part axially movably disposed makes possible an adjustment of the width of the second gap which can be formed between said two parts.

[017]   Thus is made possible a control as needed of the second gap. The second gap constitutes, like the first gap, a magnetic resistance in the magnetic circuit. The larger said gap widths are, the greater the magnetic resistance and weaker the magnetic field in the magnetic circuit. The position of the second part of the magnetic core which determines the size of the second gap, therefore, affects the magnetic resistance in the magnetic circuit and consequently the strength of the magnetic field.

[018]   This means that, for example, a large second gap altogether weakens the magnetic field and thus the magnetic force is reduced between the first part of the magnetic core and the magnetic armature. The regulation, via the electric current

on the magnetic coil in this case, is less sensitive on account of the high magnetic resistance. The gradient of the p-I characteristic line is then smaller than in a small second gap, which means that the current sensitivity of the pressure adjustment is lower and thus is given a high cancellation of the possibility of pressure adjustment. This advantageously takes effect above all in the low-pressure range, since in this range changes of pressure are particularly detectable.

[019]   The first and the second part of the magnetic core advantageously have corresponding contact surfaces the design of which in the second gap produces a radial magnetic crossing of field line between the second and the first part of the magnetic core.

[020]   The second part of the magnetic core is preferably implemented by a conic shift valve. The shape of the cone has a great influence upon the properties of the proportional magnet. The cone angle determines the portion of the radial and axial forces that can be transmitted by the magnetic flow to the shift valve and to the second part of the magnetic core. The radial forces level over the periphery. A high portion thereof is therefore to be sought. But axial forces are also needed in order to effect a stroke-dependent magnetic flow change. The axial forces should, of course, be as weak as possible, since otherwise a second regulation point generates and non-linearities can appear in the p-I behavior of the proportional pressure-regulator valve. This would result in negative regulation quality. Besides, a working point in the characteristic field would not be clearly adjustable having two regulation points. The proportional magnet should, therefore, be regulated mainly via the first gap. Furthermore, the influence of the second gap should be certain from the point of view of regulation technology.

[021]   The second magnet core is controlled by a pressure force which is preferably hydraulic but can also be produced pneumatically or mechanically. The pressure force advantageously adjusts itself according to a load requirement in the transmission, especially in case of a hydraulic control depending on a hydraulic pressure in the hydraulic circuit. The hydraulic pressure as command variable for control of the second gap is either the main pressure itself, a pressure proportional to the main pressure, or the issued pressure proper.

[022]   With the dependence of the pressure force on the load requirement in the transmission, a proportional lowering of the p-I characteristic line is possible in the partial load range.

[023]   Summarizing, the inventive proportional pressure-regulator valve can be shown with the following advantages.

[024]   The inventive proportional pressure-regulator valve and method make possible two effective engagement parameters independently of each other for the control of a pressure level, especially of a gear clutch pressure. The reduced gradient of the p-I characteristic line in the partial load range produces the increase of sensitivity of the p-I.

[025]   If the issued pressure is used as command variable for the control of the second gap, it is possible to obtain a high p-I sensitivity in the low-pressure range and a correspondingly low sensitivity in the high-pressure range.

[026]   In a development of the invention, it is provided that the pressure force is axially passed into the second part of the magnetic core via a shift valve. Said shift valve can be laid non-positively on the second part of the magnetic core and preferably has the shape of a hollow cylindrical sleeve which has a substantially annular pressure surface. Said pressure surface is connected with a feed line of the hydraulic circuit and, therefore, can be loaded with a hydraulic pressure force. The shift valve is thus actuated by a hydraulic pressure proportional to a load requirement in the hydraulic circuit.

[027]   This means that the second gap is controlled depending on load and thus respectively the magnetic field and the magnetic force between magnetic armature and the first part of the magnetic core are influenced depending on load.

[028]   In one other development of the invention, it is provided that the hydraulic control of the second gap be ensured via several axial holes. The shift valve does not sit directly upon the armature rod but on the pole core. The system thereby acquires a stable behavior, since the width-to-height ratio is considerably improved. Besides, this control also makes an accurate positioning of the second part of the magnetic core possible.

[029]

[030]   For better understanding the invention is now explained with reference to an embodiment and to a p-I characteristic line shown in the enclosed drawings where:

[031]   Fig. 1 is a longitudinal section of a proportional magnet with a hydraulic control of the second air gap; and

[032]   Fig. 2 is a p-I characteristic line field of the inventive proportional pressure-regulator valve.

[033]

[034]   In Fig. 1 is shown a longitudinal section of a proportional magnet 1. The proportional magnet 1 consists, among other elements, of one magnetic coil 4, one magnetic armature 3 movable in the interior of the magnetic oil, one armature rod 5 fixedly connected with the magnetic armature 3 and a two-part magnetic core. The magnetic core has one first part 2 and one second part 6. Both parts 2, 6 are disposed coaxially, concentrically and movably relative to the armature rod 5. While the first part 2 is firmly connected with the housing 11, the second part 6 is provided axially movable in the proportional magnet 1. If an electric current flows into the magnetic coil 6, a magnetic field is generated whose magnetic flow passes into a magnetic circuit via the housing 11, the magnetic core and the magnetic armature 3. At the same time, there is a magnetic source generated in a first gap 12 between the first part of the magnetic core 2 and the magnetic armature 3, which attracts the magnetic armature 3. The consequence of said movement of the magnetic armature 3 is an actuation of the control element via the armature rod 5.

[035]   With the second part of the magnetic core 6, a second gap 10 can be adjusted in the magnetic circuit which, depending on its magnitude, constitutes a magnetic resistance. The larger the second gap 10 is, the larger the magnetic resistance in the magnetic circuit and the smaller the magnetic flow. The consequence of the change of the magnetic flow is directly a change of the

magnetic force in the first gap 12 and, therefore, also respectively effects upon the movement of the magnetic armature 3 and the actuation of the control element.

[036]   The second part of the magnetic core 6 is moved by a pressure force. In the embodiment shown, the pressure force results hydraulically. A shift valve 13, which can be non-positively laid on the second part of the magnetic core 6, guides the pressure force axially into the second part of the magnetic core 6. The shift valve 13 is designed as hollow cylindrical sleeve which is located in a hole of the housing 11 and seals it as oil tight as possible. Said shift valve 13 provides a pressure surface which with a feed line 16 is connected to the hydraulic circuit which thereby is loaded with a hydraulic pressure force. The hydraulic pressure force corresponds here to the main pressure or is proportional to the main pressure or is the issued pressure proper. The actuation of the second part of the magnetic core 6 is thus dependent on a load requirement which reflects itself in the pressure level in a hydraulic circuit. There is further provided in the housing 11 a breather hole 15 in order to ventilate the space formed by the shift valve 13, the second part of the magnetic core 6 and the housing 11 and to discharge from the interior of the housing leakage oil that eventually appears.

[037]   A pressure spring 9 between the first part 2 and the second part 6 of the magnetic core again resets the second part of the magnetic core 6 as soon as the hydraulic force is reduced.

[038]   There is also provided a non-magnetic disc 17 which, on one hand, firmly connects the first part of the magnetic core 2 with the housing and, on the other, diverts the magnetic flow so that it has to flow first via the second part 2, then via the first part of the magnetic core 6.

[039]   This geometry ensures that the magnetic flow has to flow via two gaps 10, 12 the size of which can be influenced independently of each other. Thus the magnetic force, which ultimately produces respectively the movement of the magnetic armature 3 and the actuation of the control element, is adjusted by two parameters determinable independently of each other.

[040]   The first adjustable parameter is here the current strength in the magnetic coil 4 and the second parameter a variable adapted according to the load

requirement, for example, the hydraulic pressure in a hydraulic circuit. The combination of said two parameters makes possible the load adaptation of a control for a proportional magnet and achieves a favorable pressure-current sensitivity in a desired range of pressure.

[041]   In Fig. 2 is shown a characteristic line field with three p-I characteristic lines. The characteristic line a represents the p-I characteristic line with maximum size of the second gap 10, characteristic line b the p-I characteristic line with minimum size of the second gap 10 and characteristic line c the p-I characteristic line with the individual output pressure as commanding variable.

[042]   In the comparison of the characteristic lines a and b can be clearly understood that the gradient of the characteristic line b is larger than that of the characteristic line a. Therefrom is to be interpreted that the p-I sensitivity depends on the size of the second gap 10 and this in a manner such that the p-I sensitivity increases as the size of the second gap 10 increases.

[043]   The characteristic line c shows a p-I sensitivity initially of a magnitude similar to the characteristic line a. But starting from a certain value it proceeds more abruptly and approximates the curve of characteristic line b. Therefore, with the individual output pressure as command variable, a large p-I sensitivity can be achieved in the lower-pressure range and a reduced p-I sensitivity in the high-pressure range.

Reference numrals

1 proportional magnet

2 first part of the magnet core

3 magnetic armature

4 magnetic coil

5 armature rod

6 second part of the magnetic core

7 contact surface of the first part of the magnetic core

8 contact surface of the second part of the magnetic core

9 pressure spring

10 second gap

11 housing

12 gap

13 shift valve, sleeve

14 pressure surface

15 breather hole

16 feed line

7 non-magnetic disc